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AUTHORITY

Guidance ESC991242, 22 May 2003

# Search Strategies for a Wide-Field Electro-Optic Sensor

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MIT Lincoln Laboratory

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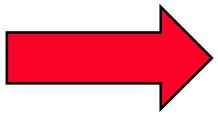
# Outline



- **Introduction and Goals**
- **Simulation Design**
- **Simulation Results**
- **Summary and Recommendations**

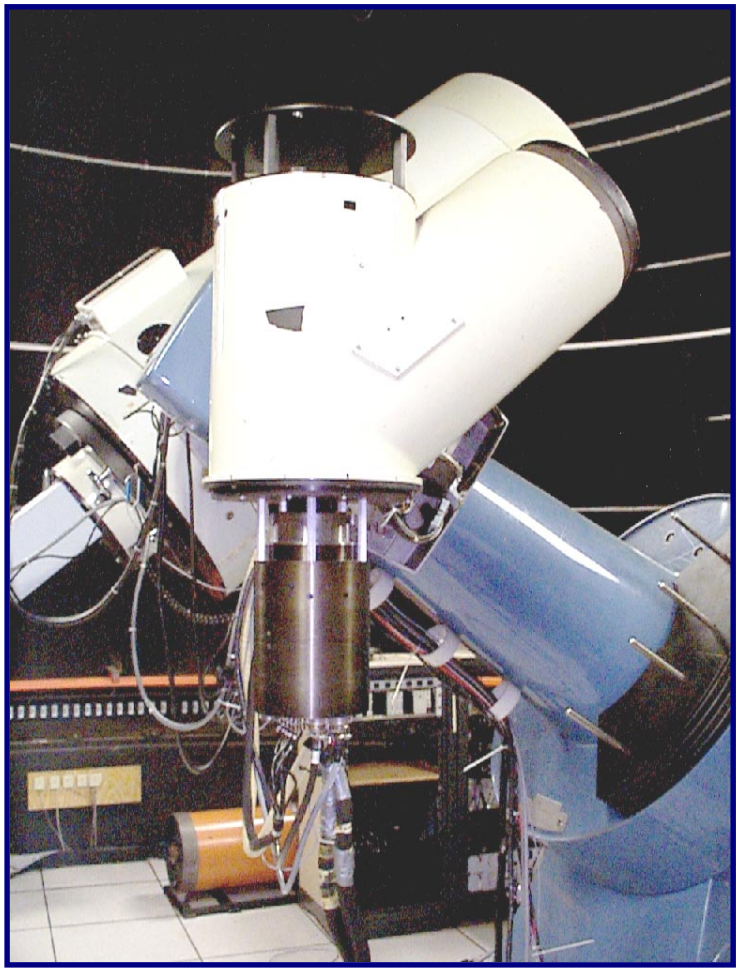
# Introduction

- GEODSS augmentation concepts under study
  - Inexpensive low-risk augmentation to deep space capacity
  - Many small tracking systems proposed and demonstrated:

    MOSS, PIMS, Raven (SATA, SOA), ASTA
- Small search systems
  - Support transition of CONOPS from tracking to search
  - MIT/LL CCID-16 imagers enabling technology for use of 40 cm class Schmidt telescopes for deep space search
  - Adequate sensitivity for >90% of current deep space catalog
- Goal
  - Develop strategies for use of 40-cm class Schmidt telescopes for deep space search and GEODSS augmentation

# GEODSS Auxiliary Prototype Telescope

- 40 cm f/1.7 folded Schmidt
  - Original GEODSS Aux prototype telescope
- Performance with CCID-16
  - Sensitivity 16.2 $m_v$
  - 5.92° X 4.54 ° FOV
  - Projected Search Rate >6500 $deg^2$/hr
- Small Search Telescope Demo



ETS 40 cm f/1.7 Telescope with CCID-16 Camera.

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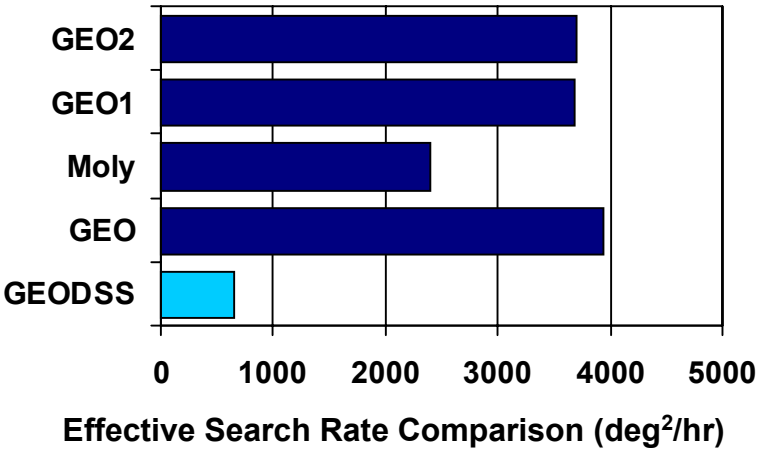
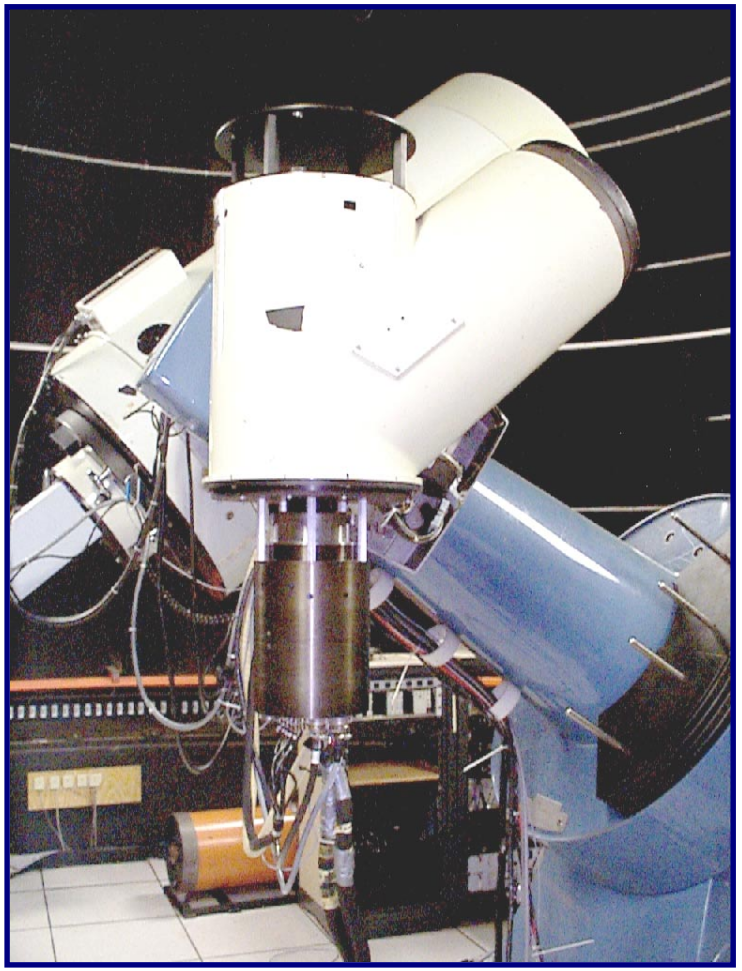


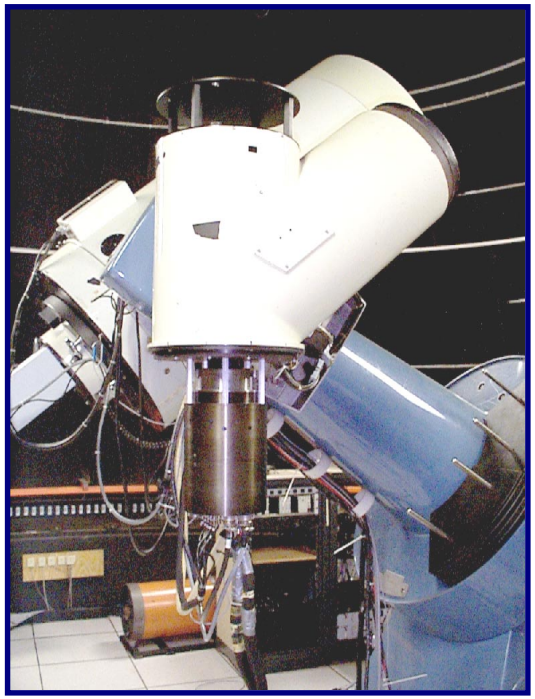

Effective Search Rate Comparison ($deg^2/hr$)



ETS 40 cm f/1.7 Telescope with CCID-16 Camera.

# ETS 40 cm F/1.7 Search Simulation Development

- **Goal:**
  - Develop search strategies to support space situational awareness using data collected during wide-field search operations
  - Cover wide range of orbit classes:
    - Geosynchronous
    - Molniya (near apogee)
    - Semi-synchronous orbits
- **Approach:**
  - Develop search strategies to maximize "leak-proofness"
  - Simulate search strategies and evaluate effectiveness
  - Test useful strategies at ETS



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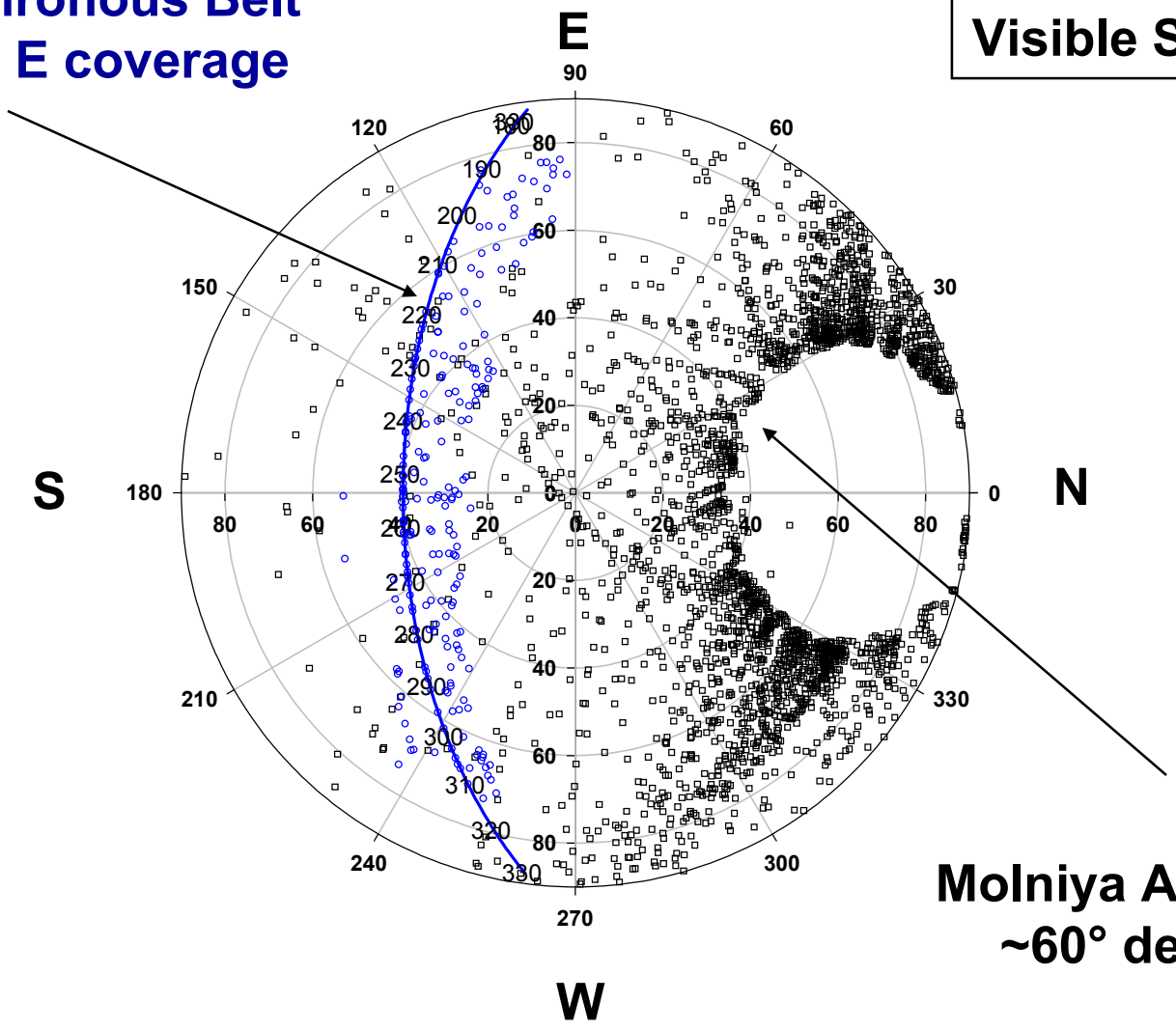
# Deep Space Population Snapshot

**Geosynchronous Belt**
**180 -330° E coverage**

**Visible Sky at ETS**




**Molniya Apogee Ring**
**~60° declination**

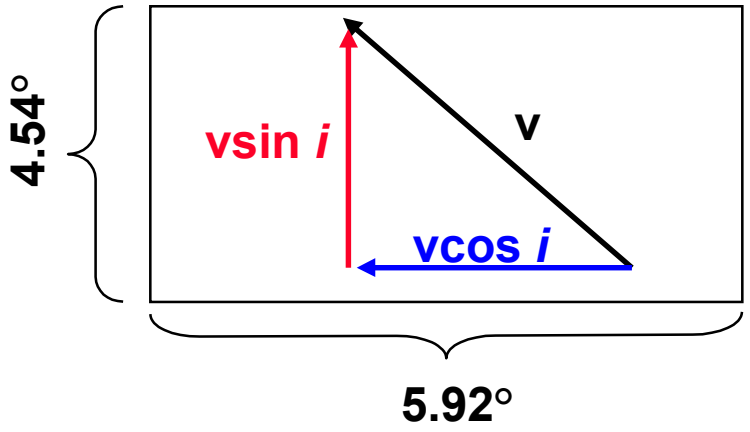
# Simulation Design: General Properties

| | |
|---|---|
| Field of View | 5.92° x 4.54° |
| Data Collection | Five 0.4-sec frames/field |
| Collection, step and settle time | 10.0 sec/field |
| Sensitivity | 15.6 $V_m$ @ 0.4 sec integration |

- GEO Belt search:
  - Align long axis of FOV (5.9°) along GEO belt, center short axis (4.5°) on GEO belt
  - Single search "stack" complete in ~4 minutes
- Molniya Ring search:
  - Cover 60° declination ring below Molniya apogee (~63°)
  - Align long axis of FOV along 60° declination line
  - Single search "stack" complete in ~4 minutes

# Simulation Design: Revisit Intervals

- Frequent revisit of fields improves "leak-proofness" of fence
- Revisit interval determined by object rates and sensor FOV
  - Goal: Revisit field before object has time to cross FOV
  - Minimum revisit time determined by short axis of FOV




| Object | Rate (arcsec/sec) | Revisit Time (min) |
|---|---|---|
| GEO | ~15 | 18 |
| Semi-Synch | ~30 | 9 |
| Molniya | ~10 | 27 |

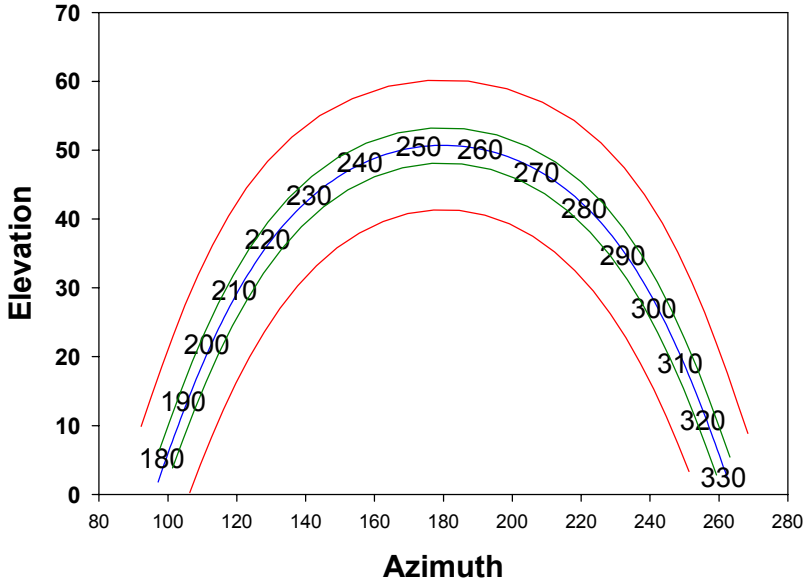
# Simulation Design: Other Concerns

- Elevation limit set at 16° – no data collection below "horizon"
- Simulation run from nautical twilight to nautical twilight
  - Simulation run for a summer night (Day 150 of 2000)
  - Weather assumed green for entire night
- Lunar "keep-out" zone in place
  - 5° + (30° * fraction illuminated): 5° at new moon, 35° at full moon
- Simulation makes use of the entire RSO catalog (~9000 objects)
- Simple analytic model used to check for objects in Earth shadow
  - Unilluminated objects considered undetectable
- Object brightness determined from SBV photometric database
  - SBV photometric observations fit to diffuse sphere model to obtain phase angle dependence

# Simulation Design: Search Patterns

- Multiple search patterns devised
- GEO belt:
  - "One stack", "Three stack", "Four stack"
    - Center all searches on GEO belt
  - Covers 4.54°, 13.1°, 17.2° latitude
    - Covers 645, 1933, 2575 deg$^2$
    - Complete in 4, 12, and 16 minutes

GEO 1-stack, 4-stack



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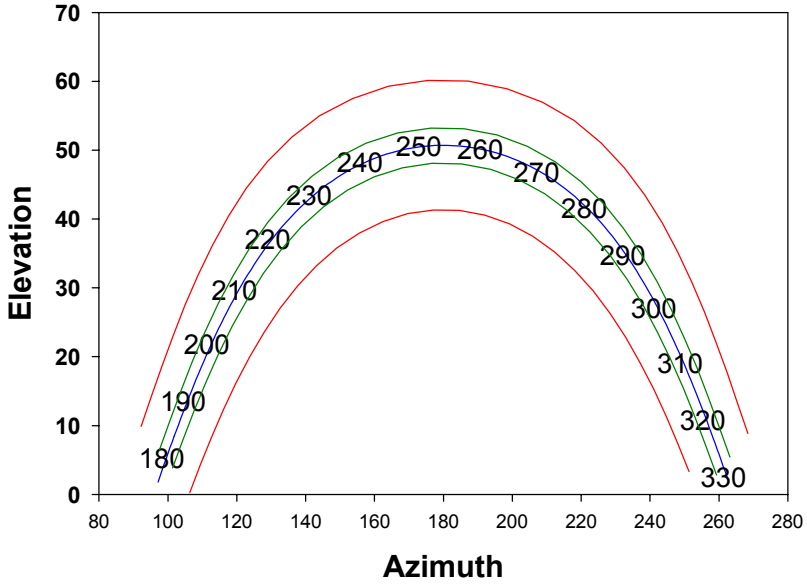
- Molniya Ring
  - "One stack" centered on 60° declination
    - Complete in 4 minutes
  - "Two stack" centered at 60° and 55.7° declination
    - Complete in ~9 minutes

GEO 1-stack, 4-stack



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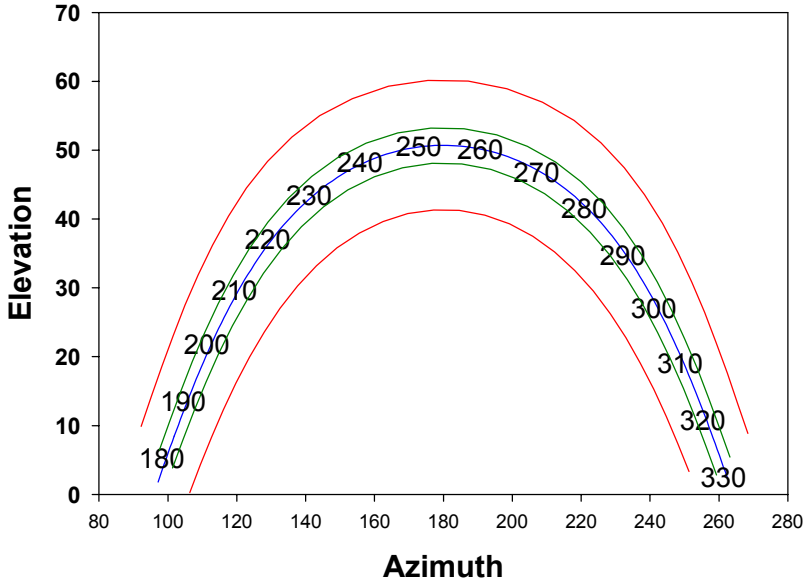


**Combinations of these search patterns examined**

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# Simulation Results: GEO "One-stack" + Molniya Ring

- "One-stack" GEO belt plus "one-stack" Molniya ring
  - Search GEO belt 3 times (~12 minutes) then divert to Molniya Ring (~4 minutes)

    Compare GEODSS search times of ~30 min for GEO belt and ~30 min for Moly ring

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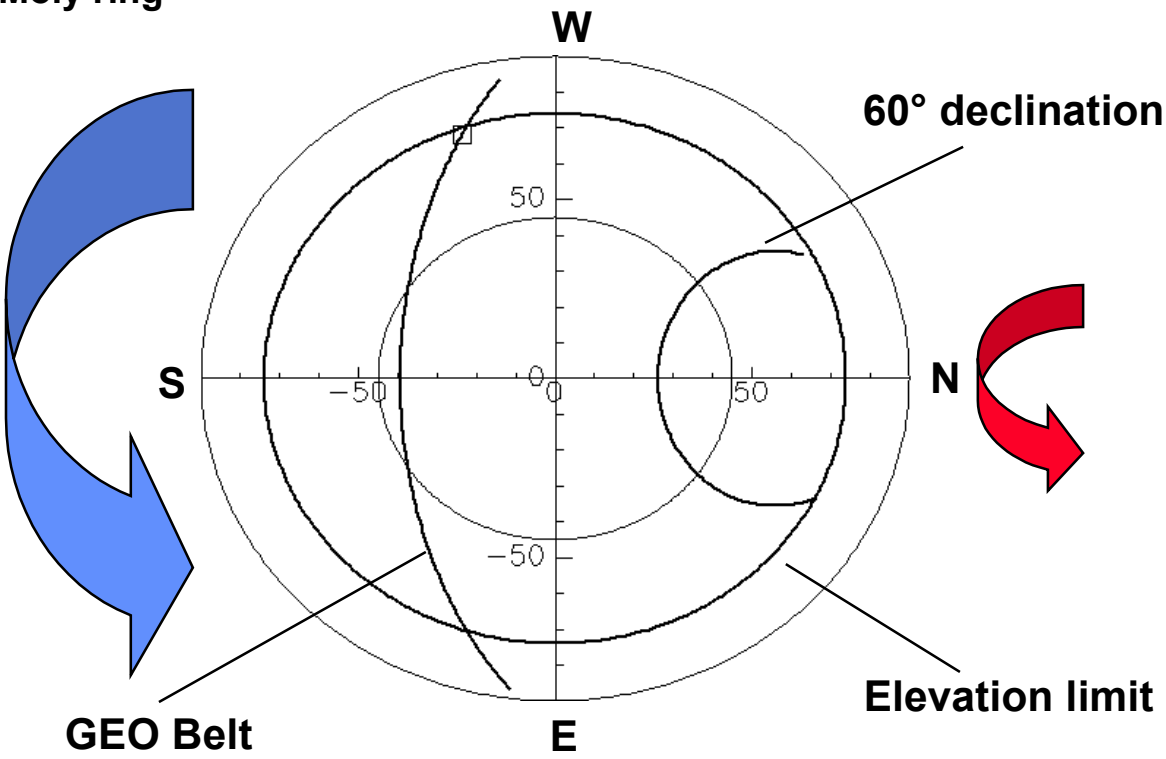

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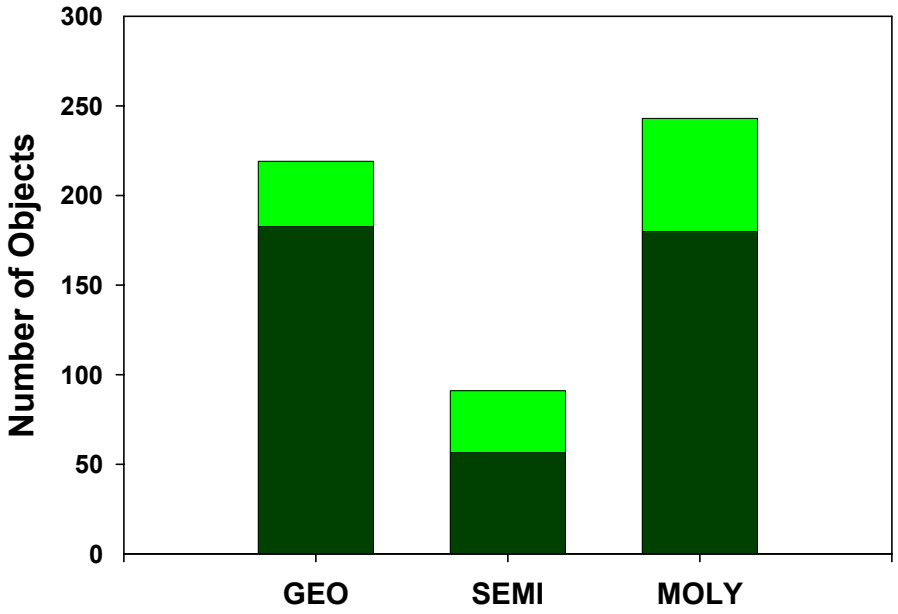
| Class | # Detected | # Visible | % |
|---|---|---|---|
| GEO | 183 | 219 | 83.6 |
| SEMI | 57 | 91 | 62.6 |
| MOLY | 180 | 243 | 74.1 |



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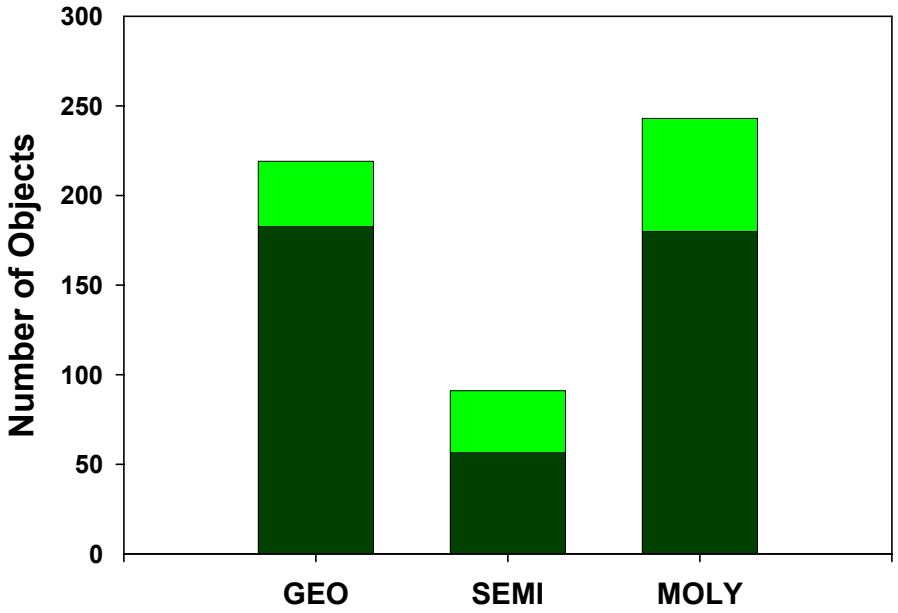


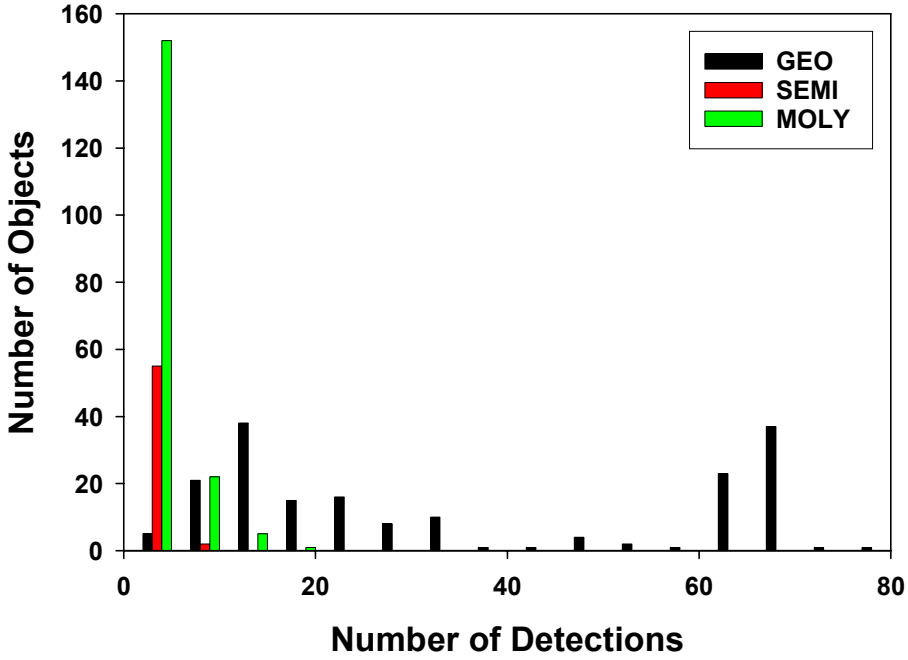

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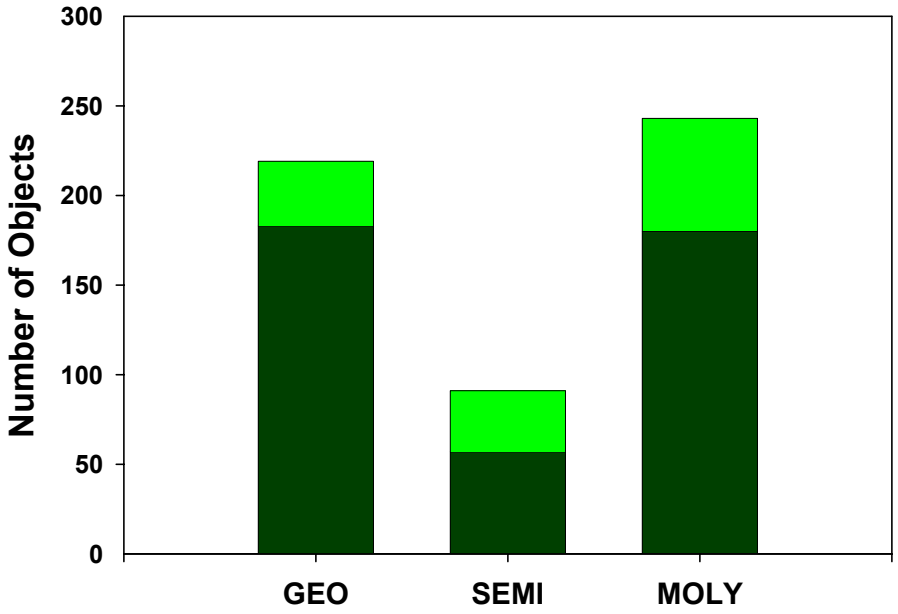
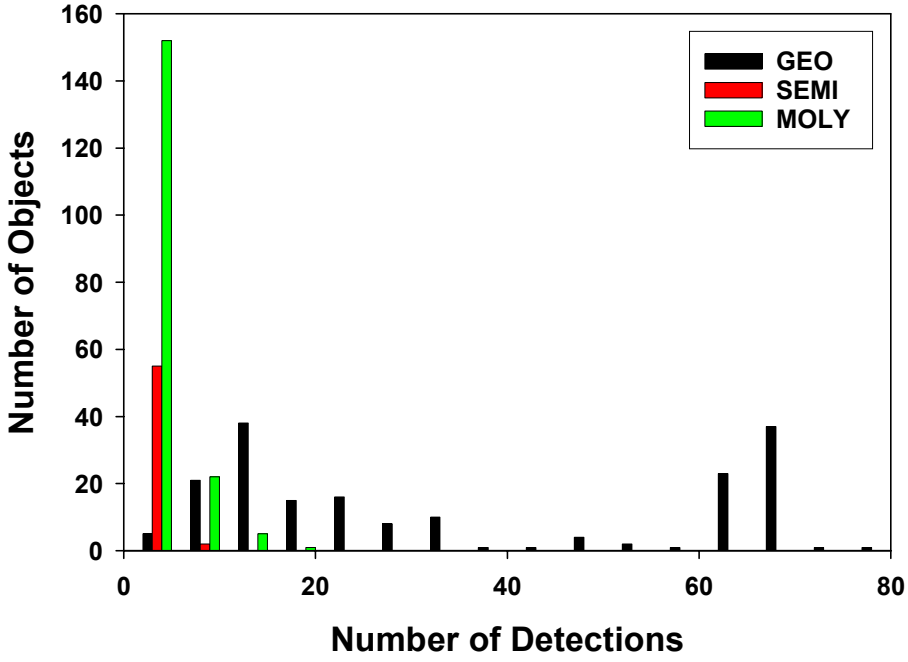
**Most visible objects detected in single night's search**



# Search Strategies: GEO "Three-stack" + Molniya Ring

- Search GEO belt 1 time (~12 minutes) then divert to Molniya Ring (~9 minutes)
  - Compare GEODSS search time of ~1.5 hours for GEO and ~1.1 hours for Moly ring

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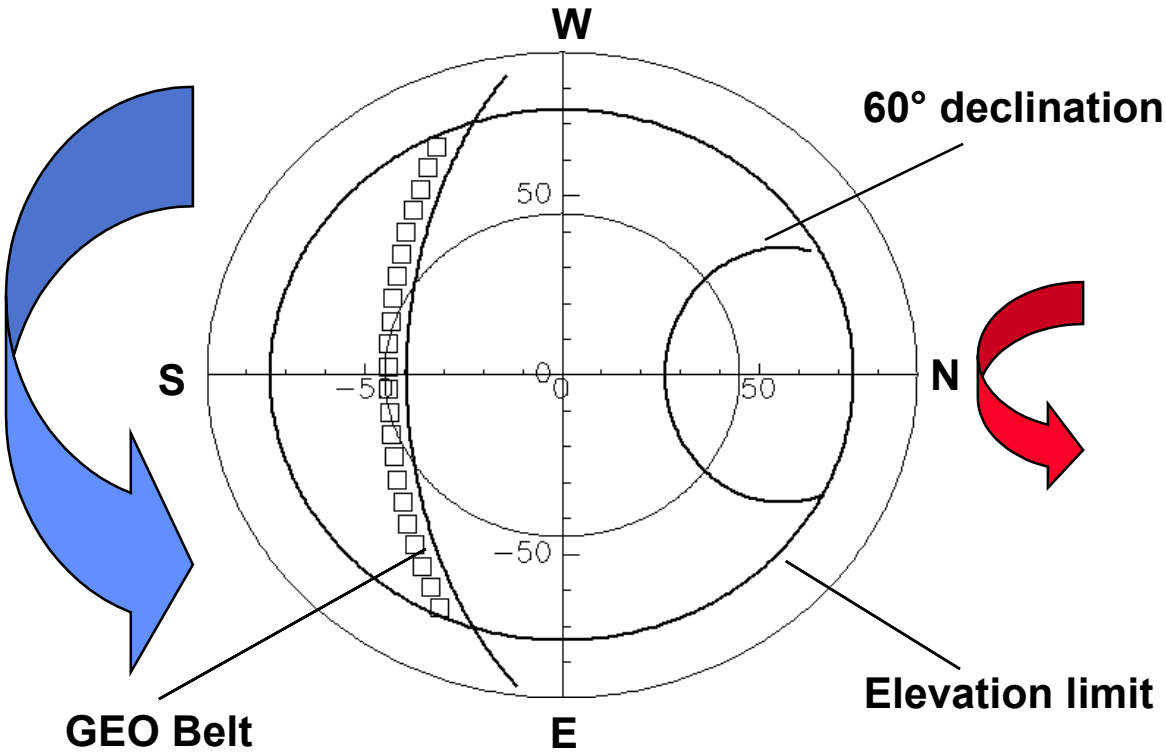

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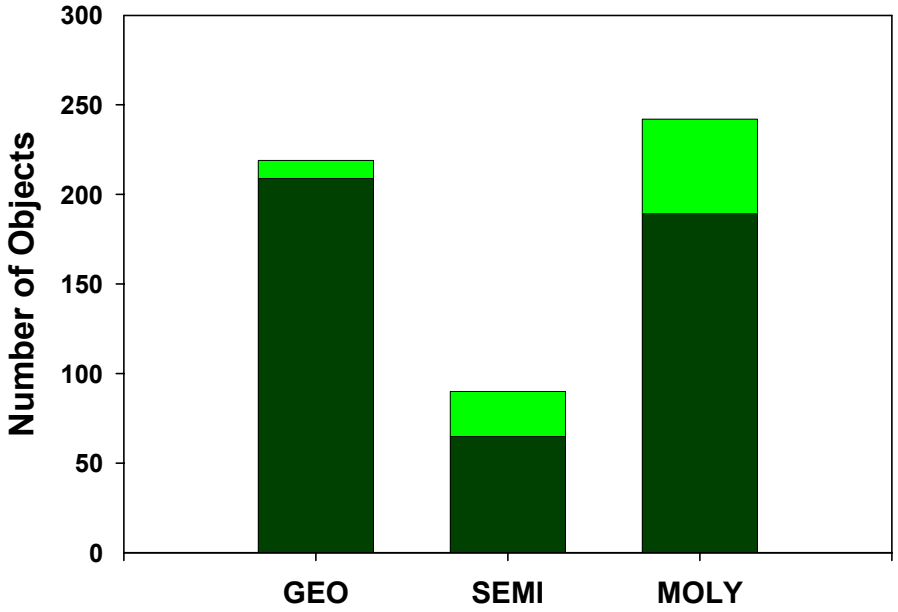

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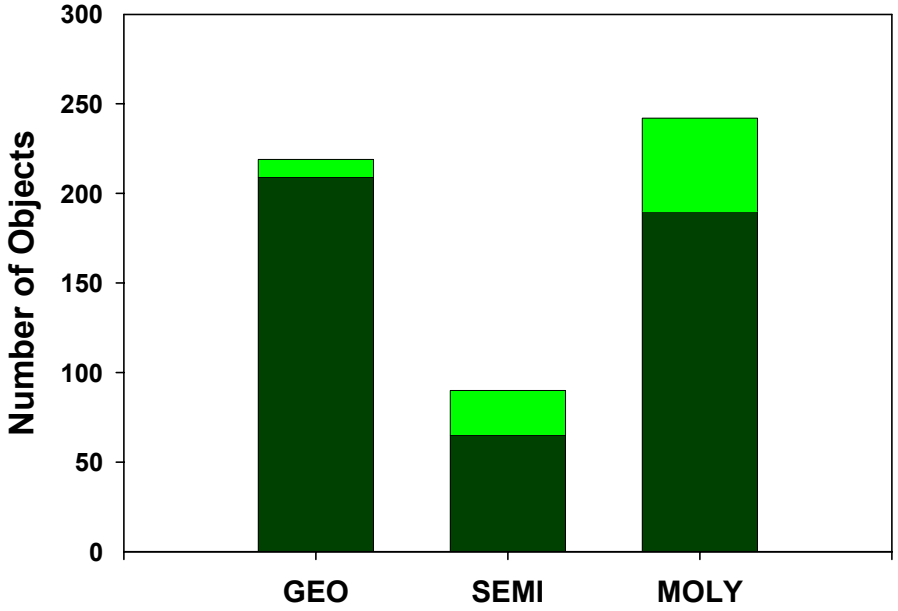


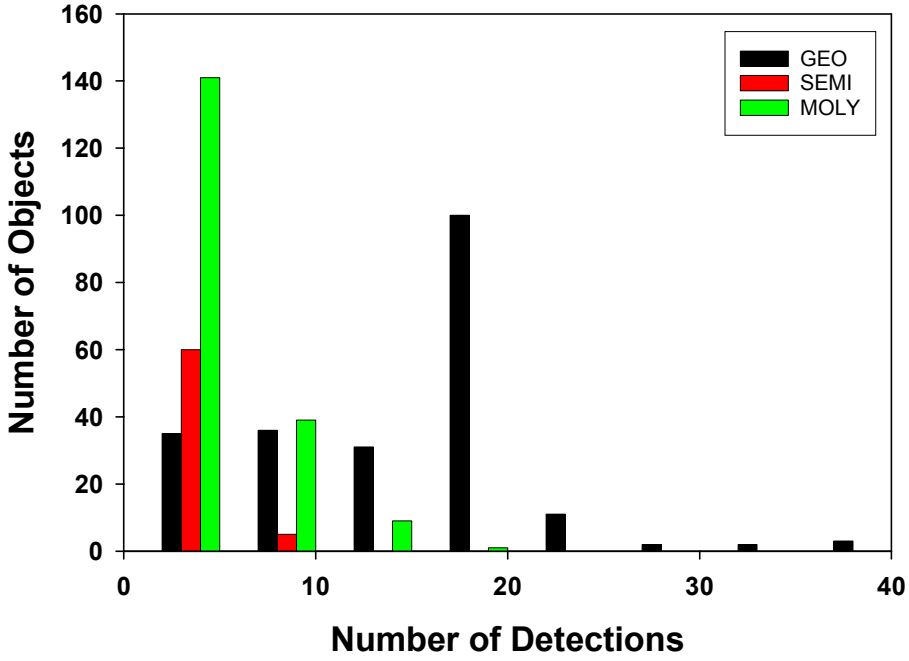

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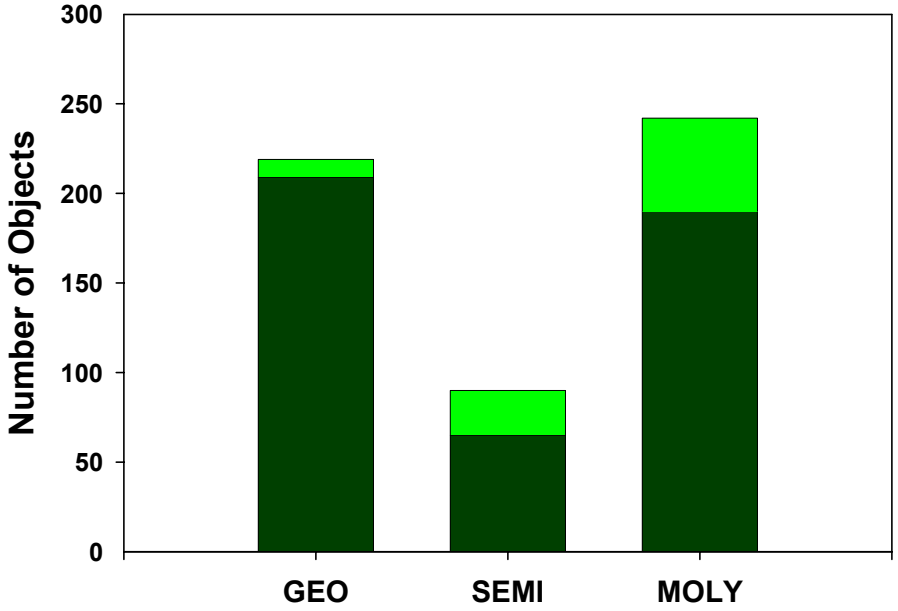
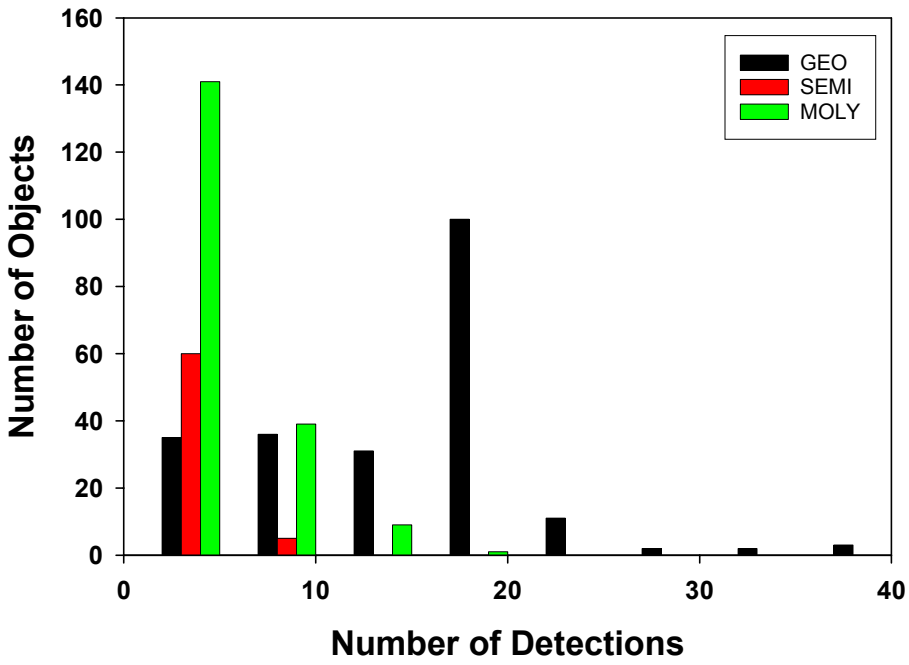
**More visible objects detected in single night's search**



# Search Strategies: GEO "Four-stack" + Molniya Ring

- Search GEO belt 1 time (~16 minutes) then divert to Molniya Ring (~9 minutes)
  - Compare GEODSS search time of ~2 hours for GEO and ~1.1 hours for Moly ring

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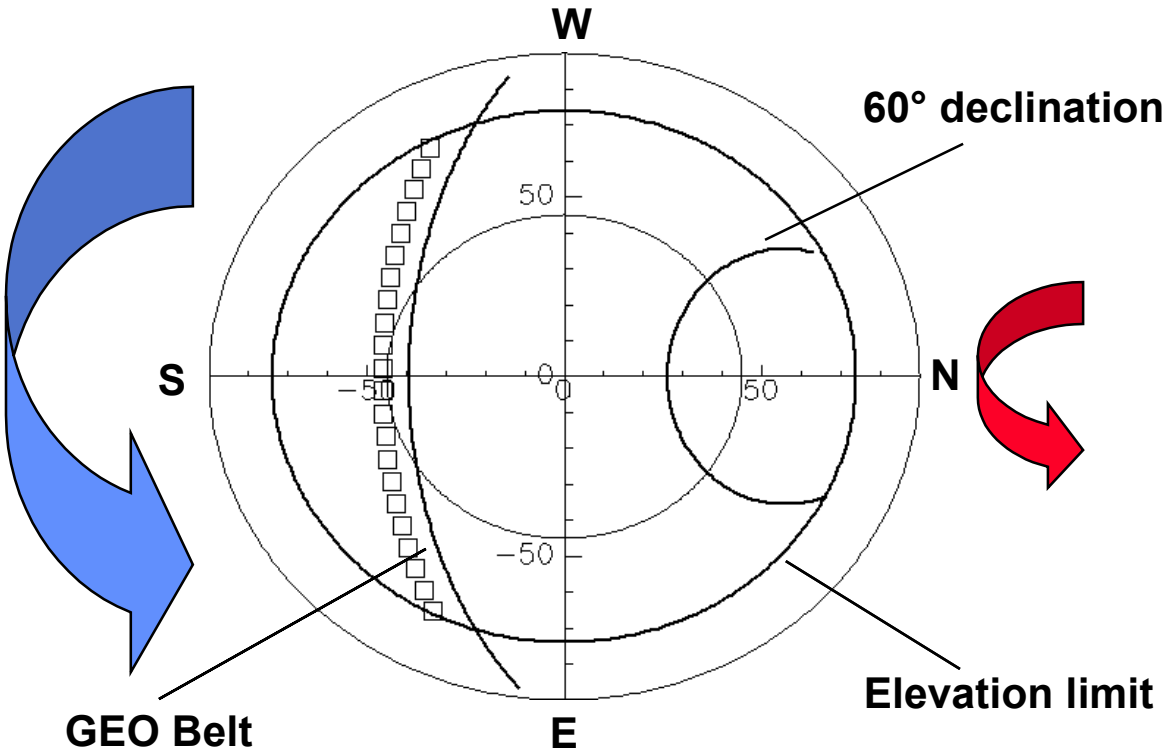

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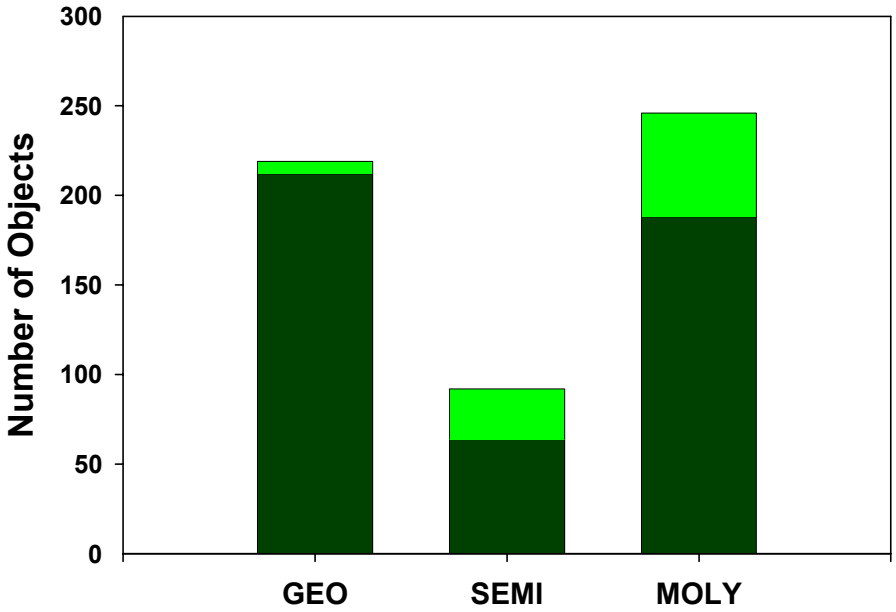

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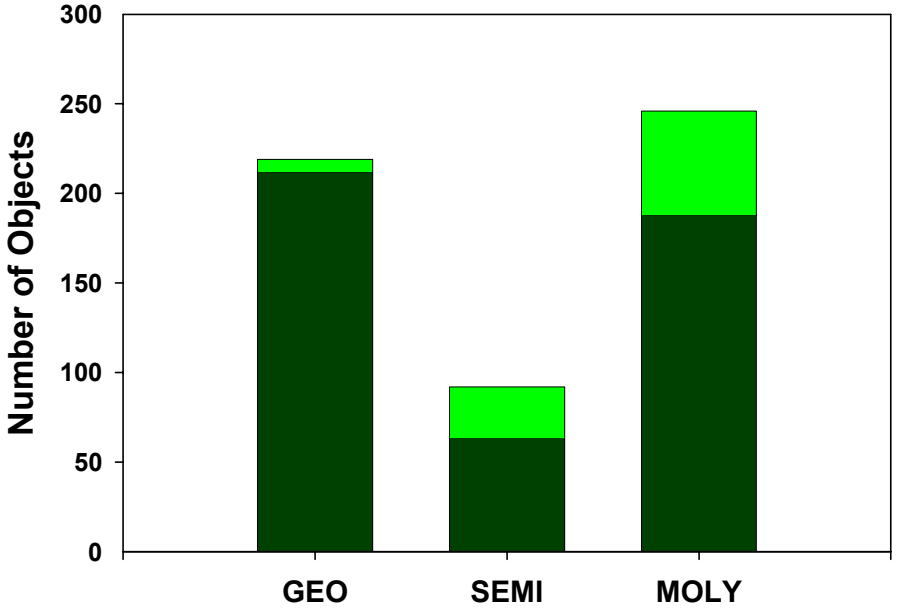


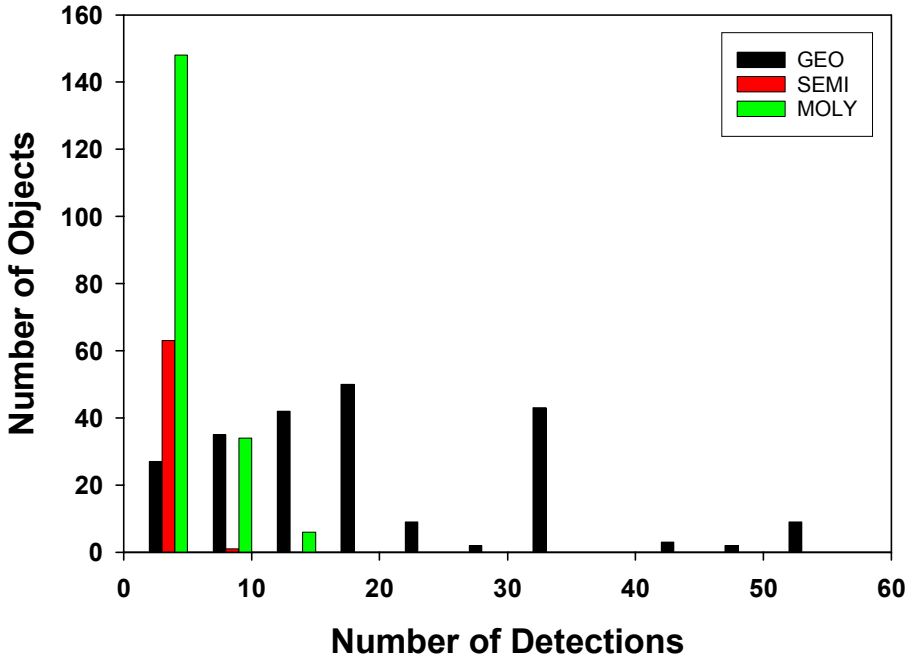

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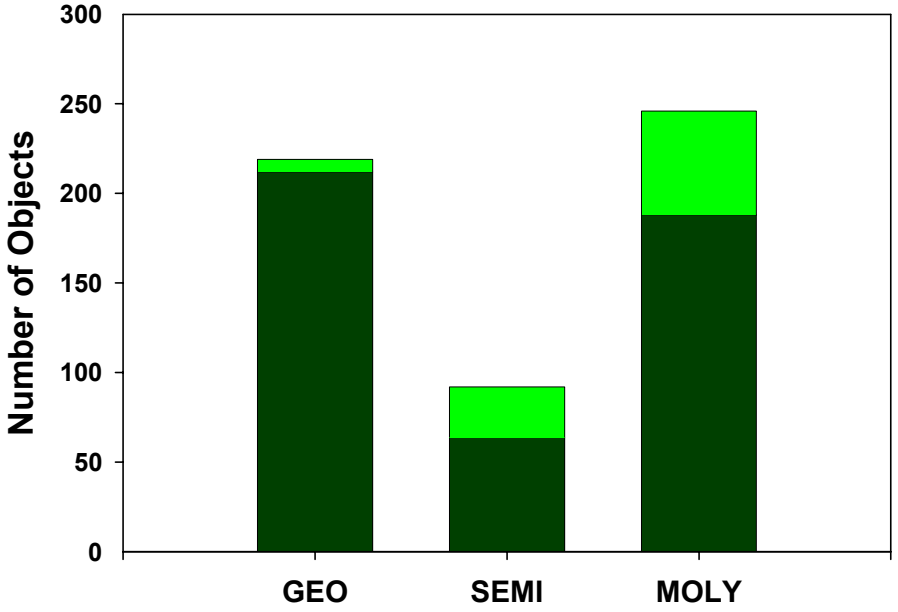


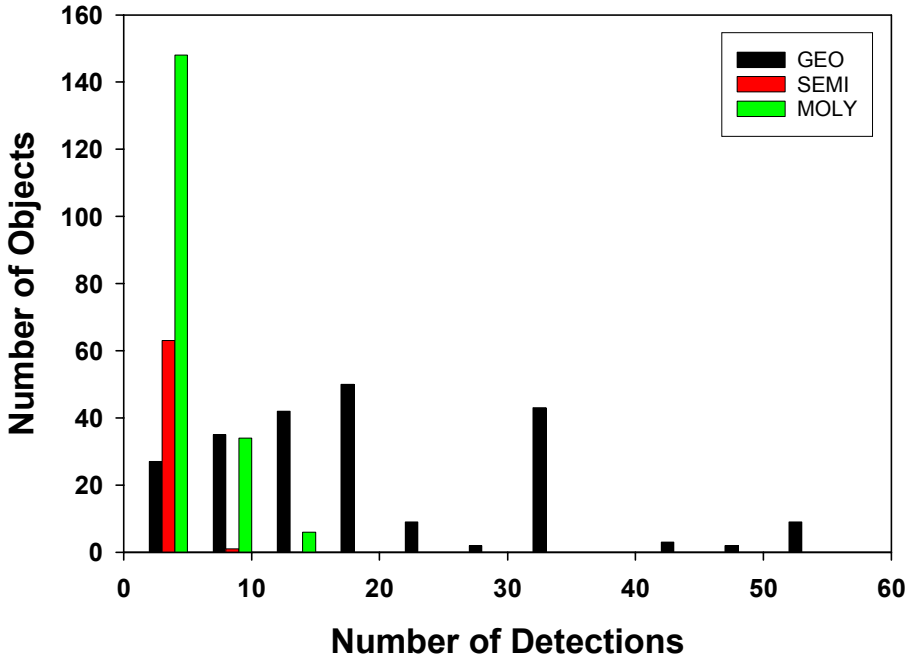

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- Results suggest that most of the visible deep space objects can be detected multiple times in a single night of search operations
- Results suggest significant search capability to augment current GEODSS tasking
  - Low-risk
  - Search rates almost 10 times GEODSS
- Testing of these search strategies planned for April-May 2001